DOCUMENT RESUME

ED 235 010 SE 043 179

AUTHOR Darch, Craig; And Others
TITLE Instructional Approaches and Levels of Practice in Working Fourth Grade Word Problems.
PUB DATE Apr 83
NOTE 32p.; Paper presented at the Annual Meeting of the American Educational Research Association (Montreal, Quebec, Canada, April 11-15, 1983).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Computation; Educational Research; Elementary Education; *Elementary School Mathematics; Grade 4; *Mathematics Achievement; *Mathematics Instruction; *Problem Solving; Student Attitudes; *Teaching Methods
IDENTIFIERS *Direct Instruction; *Mathematics Education Research; Word Problems (Mathematics)

ABSTRACT

The purpose of this study was to look intensively at two aspects of mathematics instruction--development and practice. It contrasted the Direct Instruction approach to the development phase of teaching problem solving with a Traditional approach taken from the teachers' manual of four widely used basal textbooks. Seventy-three fourth graders selected on the basis of failing a screening test were randomly assigned to one of four experimental groups: Direct Instruction or Traditional Instruction, each with a fixed amount of practice or with extended practice. Students were taught eleven 30-minute problem solving lessons in groups of two to four students. The instructional sequence is detailed. Three tests of problem solving and one consumer satisfaction questionnaire were developed and administered. Regardless of whether extended practice was provided, students taught with Direct Instruction performed on the posttest at a significantly higher level than students taught with traditional procedures. Attitudes of Direction Instruction students were also more positive. (MNS)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

requested

ED235010

Instructional Approaches and Levels of Practice in Working Fourth Grade Word Problems

Craig Darch

Auburn University

Doug Carnine

Russell Gersten

University of Oregon

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

R. Gersten

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

A paper presented in a symposium on direct instruction at the Annual Meeting of the American Educational Research Association

Montreal, Canada
April 1983

SE043179

Instructional Approaches and Levels of Practice

in Fourth Grade Math Problem Solving

A series of experimental (Good & Grouws, 1979), quasi-experimental (e.g., Gersten & Carnine, 1982; Stebbins et al, 1977) and correlational (Fisher et al, 1980; Good & Grouws, 1977; Stallings, 1975) studies seem to demonstrate that when elementary school teachers employ the set of procedures typically labeled direct instruction or active teaching, there are consistent gains in mathematics achievement for their students. A limitation of these long term field studies is that they can only assess the impact of a "package" or combination of instructional valuables. As Good and Grouws (1979) have indicated, the importance of individual variables can only be evaluated in studies that experimentally isolate specific components of the total instructional program.

The purpose of this study was to intensively look at two aspects of mathematics instruction -- development and practice. The first is what Good and Grouws (1979) refer to as development, what would generally be considered the actual teaching of the day's lesson. This component was selected as the focus of this study since Good & Grouws (1979) reported that, even with inservice training, this was "the only variable that teachers, as a group, had consistent trouble in implementing" (p. 358). By contrast, most teachers in their large scale urban study mastered the other components of the Good-Grouws teaching model (conducting daily review, assigning and checking homework daily, providing help during independent seatwork, practice or mental computation) and performed these activities with a high degree of regularity.

Good and Grouws identified three components of development: a) teaching of prerequisite skills and concepts; b) promoting student understanding of mathematical concepts by using lively explanations, demonstrations, and

illustrations; c) assessing student comprehension by asking students "process/product" questions (i.e., active teacher-student interaction).

Our experience in teacher training and curriculum development led us to believe that a more systematic and clearcut approach to development might enhance student performance. The approach utilized was based on the model of instruction developed by Engelmann and Carnine (1982) and their colleagues, called Direct Instruction. This approach calls for direct teaching of clearly articulated strategies for problem solving with explicit step-by-step teacher modeling and specific formats for assessing student mastery at each step (cf. Cohen & Stover, 198). This approach deviates substantially from the basal arithmetic series used in the Good and Grouws study (and used in a majority of classrooms in the country). Whereas traditional basal texts look at the solution of simple arithmetic story problems as a child's initial encounter with the cognitive operations involved in problem solving, Direct Instruction procedures take a more narrow, limited view of the task at hand. The goal is for students to independently solve word story problems involving multiplication and division, which involves discriminating multiplication from division (or addition and subtraction) problems. Students are explicitly taught a series of rules (e.g., "If a problem uses the same number again and again, it is either a multiplication or a division problem."), and then taught how to apply these rules. For the purposes of initial instruction, every step in the problem solving process is made overt.

Because an overt response by the learner is required at each step, the teacher is in an excellent position to diagnose any problems that students are having in the instructional sequence. If a student makes an error or fails to respond at all, the teacher immediately interjects with either a model of how to

answer correctly or some type of instructional prompt based on a previously-taught rule.

Once students are firm in their knowledge of the steps in the problem solving strategy, the strategy is covertized. Teacher questions and instructions are gradually dropped from the instructional presentation. This means that the students are no longer required to respond overtly at each step. Eventually, students perform all steps in a problem independently.

This study contrasted the Direct Instruction approach to the development phase of teaching with a Traditional approach. The Traditional approach was taken from the teachers manuals for four widely used state-adopted basal texts. Solution of word story problems was selected as the target area since it is a common problem area for students in the intermediate grades, and an area for which widely divergent philosophies of instruction are advocated. The specific topic was teaching word story problems involving division and multiplication to skill deficient fourth graders. To optimize the representativeness of the study, the number of practice problems used in the study was determined by calculating the mean number of practice problems on this topic of the four state adopted texts.

To optimize internal validity, other components of instruction--number and exact type of problems taught, and time for independent seatwork--were kept constant. Our approach followed the guidelines for classroom research developed by Gall (1977). Semi-scripted lessons were provided to experimental teachers in both conditions. This enabled teachers to adapt their responses and questions to the individual responses of students in their groups, but insured that all components of the interventions were implemented. Experimental teachers were

trained to mastery on the lessons to be presented.

The second variable in the study was provision of extended practice. It is a commonly advocated and utilized procedure for low performing or at risk students (e.g., Nagel & McLevie, 1981). We wished to explore the impact of providing more instructional time and controlled practice on the material not previously mastered. In addition, we wanted to determine if there was an interaction between mode of instruction and provision of extra practice.

METHOD

Subjects

A screening test on math story problems was given to all fourth graders in six regular classrooms in a middle sized school district in the Northwest. Seventy-three out of 220 students failed the test (accurately answering fewer than half the problems). They served as potential subjects. The classroom teachers verified that each of the subjects screened as skill deficient was experiencing some difficulty in solving mathematics story problems. To be considered eligible for participation in the study, students had to demonstrate computational ability in division, multiplication, addition and subtraction on a second test.

Subjects were almost exclusively Caucasian and came from essentially middle income families. All subjects were taught with one of the four state adopted basal mathematics programs.

The 73 students were randomly assigned to one of four experimental groups: (1) Direct Instruction with fixed amount of practice (DI-Fixed), (2) Traditional instruction with fixed amount of practice (Trad-Fixed), (3) Direct Instruction with extended practice (DI-ExP), and (4) Traditional with extended practice (Trad-ExP).

The two groups taught with a fixed number of practice problems received eleven 30 minute lessons, while the extended practice groups received up to eight additional lessons in their instructional program depending on their performance on criterion-referenced tests administered on three different days.

No significant differences were found between the four samples on screening test scores or in sex distribution. The DI-Fixed group had 7 boys and 10 girls, DI-ExP 9 boys and 10 girls, Trad-Fixed, 10 boys and 8 girls, and Trad-ExP 9 boys and 10 girls. Mean scores on the screening test were 16.12, 15.05, 15.50, and 14.90, respectively.

Setting

Students were taught in groups of two to four. Generally, instruction took place within the student's regular classroom; occasionally an empty classroom was used. The number of students per instructional group was determined by two logistical issues: (a) the number of subjects in each classroom, and (b) the ratio of male and female subjects. When teaching took place in the classrooms, students sat in desks in a semicircle facing away from the rest of the class; the experimental teacher sat in front of the students. Each lesson lasted approximately 30 minutes for all four experimental groups. Though there were occasional differences in session lengths, they were quite small and unsystematic in nature.

Teachers and Teacher Training

The experimental teachers, four graduate students in special education, all had previous teaching experience. Each teacher taught at least one instructional group from each of the four experimental conditions.

Prior to the study, the experimental teachers received training in the

procedures for each of the experimental conditions. Training was conducted over a two week period. The teacher practiced the lessons for each of the treatment conditions using role playing techniques. The experimenter gave extensive feedback to the teachers concerning their performance during these sessions. If the experimenter detected an error in presentation, he provided a model of the correct method of presentation. Practice on that aspect of the lesson was then provided. These procedures closely paralleled the teacher training procedures currently in use in Direct Instruction Follow Through programs (Morimitsu, 1979; Carnine & Gersten, in press).

Treatments

Common Features of Both Instructional Treatments

Though the students in the Direct Instruction and Traditional groups were taught with different instructional methods, the two instructional treatments had several features in common. In both treatments identical multiplication and division story problems were used for both teacher demonstrations and independent seat work. The number of problems utilized during treatment was identical --the mean number of the four state adopted texts.

Another similarity was the use for each intervention of detailed, semi-scripted teaching manuals that carefully guided the teacher-child interaction. Their purpose was to facilitate accurate implementation of both treatments. (See Gall, 1977).

Both Traditional and Direct Instruction groups received a combination of 15-20 minutes of teacher-led instruction and 20 minutes of independent seat work on story problem worksheets. During independent seat work, students were given worksheets with story problems that asked them to apply the processes and procedures they had been taught earlier. Teachers took a low profile during this

phase of instruction. They were available to answer any questions students had concerning the story problem process. The teacher systematically reinforced the students for appropriate social behavior and accurate work. Unique features of each treatment are described below.

Traditional Instruction

The traditional instructional materials were a composite of the four mathematics programs adopted by the State of Oregon for use in elementary level classrooms. Two major aspects of development that these materials advocated were guided instruction and corrective feedback.

Guided Instruction. The Guided instruction portion of the lesson involved two components: (a) discussion designed to increase student involvement and motivation, and (b) teacher presentation of strategies to solve problems.

The teacher used group discussion to introduce various problem types. Generally, the teacher attempted to guide the discussion with questions that served to prompt the students to see information in the problem. Typical questions were, "What numbers are given to you in this problem?" "Are there any key words that may help you decide what the correct operation is to solve the mathematic problems?" Regardless of the questioning strategy used, the teacher would attempt to include all the students in the discussion, giving special attention to any students who appeared to be having difficulty. During discussions, students were often asked to articulate why they chose a particular operation.

Activities were designed to draw from the student's daily life experience. For example, students were presented with a picture taken from a magazine and then were asked to write story problems based upon the story being told by the

picture. One activity had the students bring in newspaper ads so they could make up story problems based upon experiences they had shopping with their families.

The second key element in the guided instruction was presentation of methods for developing problem solving strategies. This aspect appeared in each of the four state adopted texts. The method presented by Bolster et. al. (1978) was included in the intervention.

A four step system was presented to the students using the diagram below:

1. Place Numbers here	2. Identify correct operation	3. Write and complete number sentence	4. Place your answer here

Step 2 was the crucial one. Teachers were told to ask students exactly what the story problem was asking for. Much of the teacher presentation and student discussion was directed towards this end. Teachers required students to (a) restate a problem in their own words (to demonstrate they understood the language of the story problem), (b) identify the information given in the problem and determine what information was missing, (c) identify the question posed by each individual problem, and (d) discriminate between the information that was necessary to solve the problem and any unnecessary information.

If the students could not come up with the correct solution on their own, the teachers modeled how to choose the correct operation. They discussed each conceivable operation with the students, and identified the reasons why the other operations were inappropriate.

After the students chose an operation, they went ahead with the actual computation of the answer. If any students needed help with the computational pro-

cedures, the teacher provided assistance. (Little instructional time was utilized to actually teach students to compute.)

A final procedure in each lesson for the teacher to generate discussion with the students to ensure that individual students understood how they arrived at their answers. The teacher reintroduced questions posed earlier and asked students to restate their decision making processes. Special attention was given to any students who expressed confusion about how particular answers were obtained.

Corrections. The corrections procedures were developed from an analysis of the manuals of the four state adopted texts. To increase the fidelity of the correction procedure, an editor from the Scott Foresman Co. was asked to articulate the procedures for correction of incorrect student responses. The editor replied by asking whether the experimenter was a teacher. When the experimenter replied in the affirmative, the editor said that he should draw upon his experience of working with children for guidance. When the experimenter repeated the question, she replied that the teacher should continue with the same procedures indicated in the teacher's manual for initial teaching.

The following correction procedure was decided on. When a student made an error, the teacher identified the type of mistake, and made sure the student was aware of why this was an error. The teacher used the opportunity to generate student discussion about the mistake, guiding the discussion towards other possible correct problem setups. If the students as a group did not come up with the correct answer within 3 minutes or so, the teacher provided the answer.

Direct Instruction

The Direct Instruction intervention for this study closely paralleled the

procedures that appear for teaching story problem solving in the modules on multiplication and division in the Corrective Mathematics program (Englemann & Carnine, 1981a, b).

Introduction of Multiplication Story Problems. Students first learned to discriminate multiplication problems from addition problems. The rule students were taught was: "If you use the same number again and again, you multiply." This rule was first applied to concrete models, such as groups of boxes, some with the equivalent number of boxes and some not. The students were required to indicate whether the total number of boxes could be determined by multiplying or only by adding. Initially this practice was teacher guided, but soon the students were asked to complete this type of discrimination independently.

Next, the teacher introduced actual word problems. In the first type, the word each or every signaled that the same number was used again and again, and thus the problem called for multiplication. In the second type, the word each or every did not appear; students had to decide on their own whether the same number "was used again and again." Below is an example of an instructional format that taught the student to discriminate between multiplication and addition problems.

Teacher: If you use the same number again and again, what kind of problem is it?

Children: Multiplication

Teacher: I'll say sentences. You tell me if the same number is used again and again.

A man ran 5 kilometers on Monday, 5 kilometers on Tuesday, and 5 kilometers on Wednesday. Is the same number used again and again?

Children: Yes

Teacher: What number is used again and again?

Children: 5

Teacher: So do you multiply?

Children: Yes

Teacher: New problem. A child bought 5 pens, 7 pencils, and 3 erasers. Is the same number used again and again?

Children: No

Teacher: So do you multiply?

Children: No

Teacher: There are 6 blocks in the first pile, 6 blocks in the second pile, and 6 blopcks in the third pile. Is the same number used again and again?

Children: Yes

Teacher: What number is used again and again?

Children: 6

Teacher: So do you multiply?

Children: Yes

The teacher modeled and guided the students through several of these exercises, then the students worked problems independently.

Prerequisite Skills and Concepts for Division. These exercises introduced the students to the concept of "number families" and the relationshps between the "big" and two "little" numbers in each family. The purpose in teaching this concept was to show students the principles unifying the operations of multiplication and division. The members of one number family are 2, 5, and 10. An example of how a number family appears is: $\begin{matrix} 2 & 5 \\ & 10 \end{matrix}$. Early lessons teach students that the numbers inside the brackets are the smaller numbers while the larger number is positioned under the bracket (10 in the example). The students learn that with any number family four mathematical facts can be identified, two

for multiplication (e.g., 5 x 2 = 10, and 2 x 5 = 10) and two for division (e.g., 10 : 2 = 5 and 10 : 5 = 2). Later, students learned that where the big number was not given, they multiplied to determine it. For instance, for 2 · 5 , the students multiplied 2 x 5. Conversely, when the big number was given,the students divided. For 2) 10, the students divided two into ten, $2\overline{)10}$.

Before students could apply the "big number" analysis to story problems, the students had to learn to determine whether the big number was given in a story problem. The following instructional format illustrates how students were taught to identify the big number in story problems.

Teacher: These are story problems for multiplication or division. You're going to figure out whether each problem gives the big number.
Problem A: Mattie loved to read books so every day Mattie read 3 books. Mattie read 18 books in all. How many days did Mattie read books?
What's the big number in that problem?

Children: 18

Teacher: The problem tells how many there are in all. That's the big number.

Teacher: Problem B: Every time Jack fed the dogs, he used 7 cans of food. He fed the dogs 28 times. How many cans of food did Jack use in all?
What's the big number?

Children: It's not given.

Teacher: The problem doesn't tell how many cans of food Jack used in all.

Teacher: Problem C: Every week Ron ate 5 cookies. Ron ate cookies for 50 weeks. How many cookies did Ron eat in all?
What's the big number?

Children: It's not given.

Teacher: The problem doesn't tell how many cookies Ron ate in all.

The initial teaching procedure provided the students with information about

cues in the wording of a story problem that told whether the big number was given. For example, they learned that a number that "goes with two different names" (such as balls in a bag or books on a shelf) cannot be the big number. Students also learned that the object name that goes with each or every is related to the number that is used again and again, not with the big number.

Introduction of Division Story Problems. After the students were taught to determine whether the big number was given, the teacher guided them through several multiplication and division problems. To determine whether a word problem called for multiplication or division, students were taught to apply two rules that were initially introduced with number families:

"If the big number is not given, the problem is a multiplication problem. If the big number is given, it is a division problem."

The teacher indicated that all the problems were either multiplication or division, presented a problem, asked whether the big number was given, and finally whether multiplication or division was appropriate.

Discriminating Type of Problems. In the final step of the teaching sequence, students learned to ask two questions to discriminate between addition, subtraction, multiplication and division story problems. An illustration of this two-question strategy follows:

Teacher: I'll read story A. See if the story deals with the same number again and again. Vic drinks water 6 times every day. After 42 days go by, how many times will Vic have drunk water? Does the story deal with the same number again and again?

Children: Yes.

Teacher: So what two kinds of problems could it be?

Children: Multiplication or division.

Teacher: Listen to the story again. See if the story gives the big number. Vic drinks water 6 times every day. After 42 days go by, how

many times will Vic have drunk water?
Does the story give the big number?

Children: No.

Teacher: So what kind of problem is it?

Children: Multiplication.

Correction Procedures. Several procedures suggested by Silbert, Carnine, and Stein (1981) were used. First, the experimental teachers were trained to decide whether an error resulted from inattentiveness or lack of skill. To do so, the teachers identified what the student was doing before the question was asked. A student looking away from the teacher presentation was probably not attending. To correct non-attending "errors" (or no responses), the experimental teacher would reinforce other students for attending to the instructional presentations. When a previously non-attending student would start to become actively engaged in the instructional process the teacher would increase the amount of reinforcement for that student.

The correction procedures for errors that appeared to be due to lack of knowledge or skill were quite different. The teacher generally implemented a two step strategy. First the teacher would correct the specific error by modeling the appropriate response. Next the teacher would prompt the students by asking questions from the previously taught explicit problem solving strategy. After the student's mistake was corrected, the teacher returned to the beginning of the problem-solving strategy and presented all steps in the process again. Corrections were done individually unless more than one student was making similar errors. In those cases, the corrections were presented as a group activity.

Amount of Practice

The second independent variable in this study was provision of extended practice. Within each treatment condition, students were randomly assigned to either a Fixed Practice or Extended Practice condition. Subjects taught with a fixed number of lessons received eleven 30 minute instructional sessions. Those eleven lessons included 60 multiplication and 60 division practice problems. The choice of 120 problems as the number for the fixed practice conditions was determined by the mean number of problems presented in this topic in the four state adopted mathematics texts. A story problem was considered a practice problem if the students were required to set up the problem and solve it.

The subjects in the two experimental groups that were taught with Extended Practice received the same 11 instructional lessons that the DI-Fixed and Trad-Fixed groups received, plus up to eight extra practice lessons. At each of three evaluation points, Extended Practice students were given a ten item quiz on the past three or four lessons. Any Di-ExP or Trad-ExP student who failed to perform with at least 90% accuracy was placed in the extra practice branch of the instructional sequence. Eight extended practice lessons were generated, two after Lesson 4, three after Lesson 8 and three after Lesson 11. After receiving extra practice sessions, the students were placed directly back into the next regularly scheduled lesson, even if they had not reached mastery. If some students in the instructional group met mastery without needing any extended practice lessons, those students still came to the instructional session, but while the other group members received their extra practice lessons, they practiced computational skills by doing work sheets provided by the regular class teacher.

During the extended practice lessons, the students were provided with both extra instruction and practice story problems (10 per lesson). Extended practice lessons were designed to teach the skills that the students had previously

failed to master. The formats were similar to those used in the previous lessons, but used different examples. These lessons were also scripted.

Measures

Three tests of problem solving and one consumer satisfaction questionnaire were developed for this study. The problem solving tests were a 40 item screening test, a 26 item posttest, and a 26 item maintenance test. The Screening Test was composed of two parts. The first part included 16 computational items, 4 each of addition, subtraction, multiplication and division. To be scored as a pass, the student needed to accurately complete at least two of the four items on each basic arithmetic operation. The second part involved 24 story problems: 9 multiplication, 9 division, 2 addition and 4 subtraction. To serve as a subject, students could score no higher than 50%.

The Posttest was a 26 item test that contained 11 multiplication problems, nine division story problems, two addition story problems, and four subtraction story problems. The addition and subtraction problems served as distractors so that the students had to discriminate among all four operations. Four items were selected from the Intermediate Level of the Metropolitan and California Achievement Tests; the remaining items were developed by the research staff. The posttest was administered the day after the last day of treatment and took approximately thirty minutes for most students to complete. Students were, however, given as much time as necessary to complete the test. The test was designed to specifically evaluate the students' performance on the curriculum presented by the instructional treatments. Students were assessed on the ability to write the correct computation statement but were not scored on the accuracy of their computation. Therefore as long as the student correctly set up

the problem, it was counted as correct.

The Maintenance Test was a parallel form of the posttest, administered 10 days after the posttest was completed. It contained 26 story problems (ten division problems, ten multiplication problems, four addition story problems, and two subtraction story problems). Again students were given as much time as necessary to complete the test. Most completed it in 30 minutes.

The five items on the Student Attitude Questionnaire allowed the Extended Practice subjects to rate, on a scale of 1 to 3, their opinions about the instructional procedures they received. (See Table 3 for actual items). Students were also asked, in an open-ended fashion, to write down any positive or negative comments about how they were taught. All the students in the DI-ExP and the Trad-ExP groups completed the questionnaire on the last day of the instructional intervention. It took approximately five minutes for each student to complete.

Fidelity of Treatment

Five lessons for each experimental teacher were audiotaped. The fidelity of treatment was assessed by the experimenter. Each teacher was also observed twice by the experimenter to determine that the procedures were being implemented correctly. Following these observations, the experimenter gave feedback to the experimental teachers on the correctness of their teaching procedures. It was never necessary to institute more than slight modification of any teacher's instructional procedures in any of the groups.

RESULTS

Reliability of measures. Internal consistency (coefficient alpha) indices were computed for the entire experimental sample ($N = 73$). The results were .80 for the posttest and .87 for the maintenance test. (The higher value for the

maintenance test was, in all likelihood, due to the greater variability in scores on the maintenance test; see Nunnaly (1978). The correlation between the posttest and maintenance test was .70.

Insert Table 1 about here

Table 1 presents the descriptive statistics for the posttest and maintenance test. The mean score for each sample is converted to a percent correct to give the reader a clearer sense of the level of performance. It is interesting to observe that, on the posttest, the scores of the two Direct Instruction samples (Fixed and Extended) are almost identical, as are the scores of the two traditional samples.

Data were analyzed with a 2x2x2 analysis of variance, with two between-subjects factors (Type of Instruction and Provision of Extended Practice) and one within-subjects factor (Time of Test). The instructional group (of two to four students) was the unit of analysis (Peckham, Glass, & Hopkins, 1969). The 2x2x2 ANOVA indicated a significant three-way interaction; $F_{(1,20)} = 8.29$; $p < .02$; therefore analysis for simple main effects were performed.

Posttest

On the posttest, a significant effect was found for Type of Instruction, $F_{(1,20)} = 29.90$, $p < .01$. No effect was found for Provision of Extended Practice on the posttest, i.e., regardless of whether extended practice was provided, students taught with Direct Instruction performed at a significantly higher level than students taught with traditional procedures. Table 2 presents the

---
Insert Table 2 about here
---

posttest data from a slightly different perspective, looking at the number of students in each sample who reached a criterion of acceptable performance (80 percent accuracy). Thirty-one of the 36 Direct Instruction students performed acceptably whereas only 9 of the 37 students taught with Traditional procedures performed acceptably.

Maintenance test

A more intricate pattern emerged on the maintenance test. Here, a significant interaction was found between Type of Instruction and Provision Extended Practice; $F_{(1,20)} = 5.68$; $p < .05$. Tukey post-hoc tests indicated that the DI-ExP sample performed significantly better than either sample taught with Traditional procedures; (CR Tukey = 5.38.) The DI-Fixed group was not significantly different than any of the other three groups.

Table 3 about here

Student Attitudes

Data from the student attitude questionnaire were analyzed using the student as the unit of analysis. Mean scores for all 5 items are presented in Table 3. It is interesting to note that students in both groups felt the topic was an important one (Question 2). However, significantly more Direct Instruction students tended to like the way the unit was taught than children taught with Traditional methods (Question 3). DI students tended to use the rules they learned to solve problems in the regular classroom more frequently than students in the Traditional group (Question 5). Unlike the Traditional students, DI students perceived that they "learned a lot from the unit." (For Question 1, the DI mean was 2.88 on a 1 to 3 scale, versus 2.05 for Traditional). Note that the students' perceptions (on Quesiton 3) seem to accurately mirror their actual

performance on the posttest.

These differences were also reflected in the students' written comments at the bottom of the questionnaire. There appeared to be some dissatisfaction with the procedures used in the Traditional treatment; some students wrote that they enjoyed neither the discussions nor making up story problems. This was in contrast to the majority of Direct Instruction students who wrote comments such as "I liked using rules to work problems."

DISCUSSION

In 1966, Jerome Bruner wrote: "A theory of instruction must specify the ways in which a body of knowledge should be structured so that it can be most readily grasped by the learner. A theory of instruction should specify the most effective sequences in which to present the materials to be learned" (p. 41). This study was an attempt to identify and detail a structure and sequence for teaching story problems that would make a difference in the acquisition of this material by low performing students. Two very different approaches towards presentation of new concepts and material (what Good and Grouws [1979] call development) were contrasted.

Regardless of whether additional practice was provided, the Direct Instruction approach led to superior performance on the posttest. Mean scores for both DI samples were in the 80% to 85% accuracy range (DI-ExP 85% and DI-Fixed 81% correct) while the traditionally taught students scored in the 60% range (Tra-ExP 65% correct, Tra-Fixed 61% correct) (see Table 2). The difference on posttest performance between the DI groups and the Traditional groups on the posttest is 1.49 pooled SD units, meeting the commonly set criteria of educational significance (Tallmadge, 1977). Most students taught with a tradi-

tional method failed to perform at an acceptable level even though they were given intensive small group instruction. Providing up to eight additional remedial lessons did not enhance their performance.

The results support the position that a program that is constructed to (a) teach prerequisite skills in a sequential manner and, most important, (b) explicitly teach problem solving strategies is superior to a traditional approach with this population. The traditional model with its emphasis on discussion of alternatives and on tailoring the program to the individual interests of students would seem misguided for these children.

Traditional methods tend to view the correct solution of word story problems as a vehicle to teach the more generalized ability of problem solving. Therefore, the teaching procedures, many of them rooted in learning through discovery, take on an intentionally amorphous orientation. The teacher is regarded primarily, as a guide or facilitator, not as a teacher of specific skills. The concern with attempts to motivate students and get students actively involved in a variety of experiences may be disorienting for low performing students. Traditional approaches, in which students generate examples based upon their own experience, participate in lengthy discussions and reflect on a range of problem solving solutions, lead to limited success for many students who are learning critical problem solving discriminations for solving word problems.

Marcucci's (1981) analysis and integration of over 30 studies in word problem solving, concluded that a "guided discovery" method (much like the traditional treatment here) was no more effective than a no treatment control group. The results on the posttest parallel this finding, as do the results of large scale evaluation studies (Gersten & Carnine, in press; Stallings, 1975) in

which students taught problem solving with a Direct Instruction approach performed at a significantly higher level in math problem solving than subjects taught with either traditional approaches or discovery learning approaches. These results are also in keeping with experimental work done by Larkin & Reif (1976) in teaching principles of physics to college students.

These results are also in keeping with descriptive and correlational work done by Good and Grouws (1977). Good and Grouws (1977) found that gains in math achievement were highest when teachers asked precise questions and gave precise feedback on strategies for correct solution of the problem to students. The traditional method is particularly amorphous in this area. To insure that the student had an opportunity to discover alternative problem solutions, the programs recommend that corrective feedback by teachers be non-directive; its major purpose is to motivate the student to discuss and explore the problem further.

If one looks closely at the Direct Instruction procedures, it is clear that a lot of attention is given to the exact nature of teacher questions and corrective feedback. When an error occurred during an attempt to solve a problem, the teacher would first correct the specific error by modeling the correct answer. Next the teacher would prompt the students by asking questions from the previously-taught instructional stategy. After the students' mistakes were corrected, the teacher returned to the beginning of the problem solving strategy and reviewed all the steps in the process again. This correction and remediation process of the direct instruction model is similar to what Good and Grouws (1977) called the "diagnostic cycle" that effective teachers implement.

While the DI-Extended Practice students averaged 1.7 extra lessons, the stu-

dents in the Traditional-Extended Practice group received on the average 6.7 extra lessons. In spite of the fact that the Trad-ExP group had over three extra hours of instruction, these students scored well below both Direct Instruction groups on the posttest.

On the maintenance test, it appears that the one or two or three extra lessons presented to the DI-ExP students did have an impact. Providing one or two extra lessons at specified branching parts appeared to be effective for students in that group.

To reiterate, most skill-deficient fourth graders have been presented time and again throughout their school careers with extra instruction and practice. In most public school programs the emphasis is on allocating extra time for practice and review using the same curriculum materials. It is apparent that merely increasing the instructional time without altering instructional procedures and curriculum is not sufficient in itself to produce changes in the mathematics problem solving performance of lower performing students. Moreover, when initial instruction is reasonably effective, only minimal amounts of additional review are needed; on the average, DI-ExP students required only 1.7 extra sessions. The DI-ExP students received less additional practice than their Trad-ExP counterparts, but had higher problem solving test scores and more positive attitudes toward instruction. As Tobias (1982) noted, "... time on task does not necessarily lead to increases in achievement. What counts is how the student uses that time and what the student is thinking while studying the materials" (p. 5).

Table 1

Means and Standard Deviations of the Number of

Correct Answers on Post and Maintenance Tests of Problem Solving

	Post Test			Maintenance Test		
Training Method	M	SD	% Correct	M	SD	% Correct
Direct Instruction-Fixed Practice	22.49	1.64	86.5	19.52	3.76	75.1
Direct Instruction-Extended Practice	22.63	1.80	87.0	21.73	2.17	83.6
Traditional-Fixed Practice	16.55	4.02	63.7	17.55	4.92	67.5
Traditional-Extended Practice	16.50	2.63	63.5	13.21	1.16	50.8

[a] N = 6 instructional groups per treatment conditions

[b] Maximum score is 26

Table 2

Number and Percentage of Students who Scored at an Acceptable Level (Over 80% accuracy) for Each Experimental Sample

	Acceptable (80% or Higher)	Unacceptable (Below 80%)
Traditional-Extended Practice	3	16
Traditional-Fixed	6	12
Direct Instruction-Extended Practice	15	4
Direct Instruction-Fixed	16	1

Table 3 - Student Attitudes Toward the Unit

		Direct Inst. Ext. Practice	Traditional Ext. Practice	t	P
1.	I learned a lot from this unit.	Mean 2.88 S.D. .32	2.16 .70	5.14	.001
2.	I feel that story problem solving is important to know about.	Mean 2.77 S.D. .43	2.61 .60	<1	N.S.
3.	I liked the way this unit was taught.	Mean 2.88 S.D. .32	2.05 .87	3.77	.01
4.	I wish more units in problem solving were taught this way.	Mean 2.55 S.D. .70	2.05 .93	1.92	.10
5.	I used the rules that I learned in the unit to solve story problems during my regular math class.	Mean 2.22 S.D. .73	1.61 .77	2.44	.05

Note: Scores are on a three point scale ranging from disagree to agree (3).

[a] N = 19

References

Becker, W.C. & Carnine, D.W. Direct instruction--An effective approach to education intervention with disadvantaged and low-performers. In B. Lahey & A. Kazkin (Eds.), Advances in child clinical psychology: Vol. 3. New York: Plenum, 1980.

Bolster, L., Cox, G., Gibb, E., Hansen, V., Kirkpatrick, J., Robitaille, D., Trimible, H., Vance, I., Walch, R., & Wisner, R. Mathematics around us: Skills and applications. Glenview, Ill: Scott-Foresman, 1978.

Burstein, L. The analysis of multilevel data in educational research in evaluation. In D. Berliner (Ed.), Review of Research in Education, Vol. 8. Washington, D.C.: AERA, 1980.

Carnine, D.W. & Gersten, R. Direct instruction: A school improvement case study. In J. Osborn (Ed.), Research base for literacy. Hillsdale, NJ: Lawrence Erlbaum, in press.

Cohen, S.A., & Stover, G. Effects of teaching sixth-grade students to modify format variables of math word problems. Reading Research Quarterly, 1981, 16, 175-199.

Darch, C. A comparison of two approaches in teaching math word story problem solving to skill deficient fourth graders. Unpublished doctoral dissertation. University of Oregon, 1982.

Engelmann, S. & Carnine, D.W. Corrective mathematics: Multiplication. Chicago, Science Research Associates, 1981(a).

Engelmann, S. & Carnine, D.W. Corrective mathematics: Division. Chicago: Science Research Associates, 1981(b).

Engelmann, S. & Carnine, D.W. Theory of instruction. New York: Irvington, 1982.

Fischer, C.W., D.C Berliner, N.N. Filby, R. Marliave, L.S. Cahen, & M.M. Dishaw. Teaching behaviors, academic learning time and student achievement: An overview. In C. Denham and A. Lieberman (Eds.), Time to learn. Washington, D.C.: USOE/NIE, 1980.

Gall, M.D. The importance of context variables in research on teaching skills. Journal of Teacher Education, 1977, 28, 43-48.

Gersten, R. & Carnine, D. Direct instruction mathematics: A longitudinal evaluation of low income elementary students. Elementary School Journal, in press.

Good, T. & D. Grouws. Teaching effects: A process-product study in fourth grade mathematics classrooms. Journal of Teacher Education, 1977, 28, 49-54.

Good, T. & Grouws, D. The Missouri mathematics effectiveness project. Journal of Educational Psychology, 1979, 71, 355-362.

Hays, W.L. Statistics. 3rd Ed. New York: Holt, Rinehart and Winston, 1981.

Larkin, J.H. & Reif, F. Analysis and teaching of a general skill for studying scientific text. Journal of Educational Psychology, 1976, 68, 431-440.

Marcucci, R.G. Metanalysis of research on methods of teaching mathematical problem solving. Unpublished doctoral dissertation. University of Iowa, 1980.

Morimitsu, C. Supervision of Direct Instruction. Eugene, OR: Follow Through Project, University of Oregon, 1979.

Nagel, T. and McLevie, J. Status Report 1 on the Progress of Implementing the Achievement Goals Program in San Diego Schools. San Diego: San Diego Board of Education, 1981.

Nunnally, J. Psychometric theory. New York: McGraw-Hill, 1978.

Peckham, P.D., G.V. Glass, & K.D. Hopkins. The experimental unit in statistical analysis. Journal of Special Education, 1969, 3, 337-349.

Silbert, J., Carnine, D., & Stein, M. Direct instruction mathematics. Columbus, OH: Charles Merrill, 1981.

Stallings, J. Implementation and Child Effects of Teaching Practices in Follow Through Classrooms. Monographs of the Society for Research in Child Development, 1975, 40.

Stevens, R., & B. Rosenshine. Advances in research on teaching. Exceptional Education Quarterly, 1981, 2, 1-9.

Tallmadge, G.K. JDRP Ideabook. Washington, D.C.: U.S. Government Printing Office, 1977.

Tobias, S. When do instructional methods make a difference. Educational Researcher, 1982, 11(4), 4-9.

Footnote

Following Burstein's (1980) suggestion for multi-level analyses, the data were also analyzed using the student as the unit of analysis. In this case, analysis of covariance was used, with scores on the screening test serving as covariates. The results were similar to when the group served as the unit of analysis. A significant effect for Type of Instruction was found on the post-test and a significant interaction between Type of Instruction and Practice was found on the maintenance test. (See Darch, 1982, for details.) Omega-square indices (Hays, 1981) were computed, indicating that 56 percent of the variance on the posttest was explained by the combination of treatment and screening test, whereas only 31 percent of the variance on the maintenance test was explained by those factors.